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DANA D. HAWTHORNE

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LOCKING DEVICE WITH SOLENOID RELEASE PIN

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Attorneys
LAW OFFICES OF
DAVID L. HOFFMAN
27023 McBean Parkway, Suite 422
Valencia, California 91355
Tel: (661) 775-0300
Fax: (661) 259-1255
Customer No.: 36212

LOCKING DEVICE WITH SOLENOID RELEASE PIN

BACKGROUND OF THE INVENTION

The present invention relates to a locking device. In various environments, especially for flight vehicles and projectiles, it is necessary to quickly and reliably release structural members for deployment yet securely hold such members in a retracted position for storage, transportation, or other pre-deployment requirements.

In certain applications such as smart bombs with movable fins (for guidance), missiles with movable fins, and satellite or space vehicles and equipment with deployable panels (e.g., solar panels), it is desirable to provide a large margin of safety in design. For such situations, the fins or panels are biased towards their deployment position with a large force, often a spring force. This force must be securely and reliably held in place prior to deployment. Premature deployment could easily damage the fins or panels, or cause other problems. Failure to deploy could result in an errant bomb or missile, or a satellite's premature loss of power.

In one proposed smart bomb design, a pin supported by plastic holds a first spring-biased member in place, which through mechanical linkage holds torsion springs in place. Mechanical linkage helps reduce the force to about 200 to 300 pounds needed to hold the spring-biased member in the locked position. When the pin is released, the torsion springs will cause the fins to be unlocked and thus deployed. To obtain a quick release, a predetermined amount of explosive is ignited to break the plastic, thereby, releasing the pin.

Another system to release a locking element or pin as used in airborne vehicles and projectiles includes cutting a bolt, which holds two elements relative to each other, so as to release satellite photovoltaic panels and antenna reflectors. A further system involves weakening a nut, e.g., by cutting a portion of the nut, then exploding the nut at the time of deployment. These systems all involve destruction, and are thus cumbersome and expensive to handle, test and replace.

In U.S. Patent No. 6,224,013 to Chisolm, a tail fin deployment device uses lock balls to hold a cup member that in turn through linkage holds tail fins in a retracted position. A pin having recesses is spring-biased so that the recesses are in alignment with the apertures holding balls, but the pin is held by a lanyard in a position where its recesses are out of alignment with the balls. The lanyard is tied to the aircraft, so when the bomb is released, the lanyard comes out. Even in this design, the lanyard has to be pulled so as to overcome about 300 pounds of force from a spring. Moreover, this design necessitates hooking the lanyard to the aircraft.

Locking balls and the like have been used in various devices, such as manual positive lock pins, e.g., made by Pivot Point, Inc. of Hustisford, Wisconsin. Pressing down on a button pushes a pin so as to align a recess in the pin with locking balls. When aligned, the balls enter the recess and release a locked member.

U.S. Patent No. 6,074,140 to Cook secures a drill bit in place with a lock ball chuck. It is stated that a mechanical, solenoid or manual chuck may be used although no actual structure is shown.

U.S. Patent No. 4,523,731 to Buitekant et al. uses a manual pull pin to release a plunger in turn releasing lock balls. The lock balls hold a flight vehicle to an external

storage element. This manual release is disclosed as an alternative to the explosive severing of a bolt that held the flight vehicle and storage element together in a prior design.

U.S. Patent No. 5,216,909 to Armoogam discloses an electro-mechanical locking mechanism for selective operation of a latch. A solenoid is used to push a pin down which pushes down a bolt locking pin, enabling movement of a piston transverse to the bolt locking pin.

Other patents using various locking mechanisms include U.S. Patent Nos. 3,985,213 to Braggins, 5,628,216 to Qureshi et al., 4,289,039 to Trunner et al., 5,600,977 to Piron, and 4,565,183 to Smith.

SUMMARY OF THE INVENTION

In one embodiment, there is a locking device with a solenoid to actuate release of the lock. The locking device includes a housing with a solenoid and a metal or magnetically responsive element disposed proximate or within a coil or coils of the solenoid. The responsive element (such as a plunger) is spring biased into its locked position. In such position, a lower portion of the responsive element (plunger) holds one or more balls, for example ball bearings, in a position where they protrude from the housing. In turn, the ball or balls hold a further element in a locked position. The portion of the magnetically responsive element (e.g., the bottom of the plunger) holding the balls has a recess or recesses proximate but not in alignment with the ball or balls when in the locked position.

Actuating the solenoid by sending current through the coils moves the plunger, by

an induced magnetic field, against the bias of the spring to a release position. In the release position, the recess or recesses of the bottom portion of the plunger receive the ball or balls. The balls no longer protrude from the housing, and thereby release the lock on the element being held. This locked or held element may also be biased, e.g., spring biased to move when the lock balls are released. The locked element when released may activate, directly or in conjunction with various linkage or components, the deployment of fins, such as fins for a smart bomb, missile, or torpedo. The released member may also activate or deploy solar panels for a satellite, or other member, especially for airborne use, but may include other uses as well.

In other embodiments, the device may use a lever in place of a ball or balls, it may use staged or staggered releases, and/or it may release multiple balls at once.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a partial sectional view of a locking device in a locked position in accordance with a first embodiment of the invention;

Figure 2 is a view similar to Figure 1 but in a released position;

Figure 3 is a view similar to a portion of Figure 1 and showing a second embodiment of the invention using a lever valve in a locked position;

Figure 4 is a view similar to Figure 3 but in a released position;

Figure 5 is a view similar to Figure 1 of a third embodiment of the invention using a staggered release and in a locked position;

Figure 6 is a view similar to Figure 5 but in a first released position;

Figure 7 is a view similar to Figure 5 but in a second fully released position;

Figure 8 is a view similar to Figure 5 but of a fourth embodiment in a locked position;

Figure 9 is a view similar to Figure 8 but in a released position;

Figure 10 is a partial schematic partial perspective view of a missile or smart bomb with its fins locked in a retracted position;

Figure 11 is a view similar to Figure 10, but with the fins released and thereby deployed;

Figure 12 is an enlarged sectional partial cutaway view of a locking device in a locked position in accordance with a fifth embodiment of the invention; and

Figure 13 is a view similar to Figure 12, but in a released position.

DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

A locking device with a solenoid-actuated release pin in accordance with a first embodiment of the invention is shown in Figure 1. The device has a housing 2, which may be a nonconductive material such as plastic, or may be conductive. The device also has a metal or otherwise magnetically responsive plunger or pin 4 axially slidable with respect to the housing, a magnetic coil 6 fixed to the housing 2 (e.g., by bolting), two locking balls 8, a biasing member 10, for example a compression spring, to bias plunger 4 in a first direction, and a power on circuit 12, typically including a battery or other electrical power source, a switch or circuit to turn on the power, and a capacitor and/or a resistor connected to the coil 6, e.g., by wires 6a, 6b.

Plunger 4 has a surface 4a against which biasing member 10 presses. Plunger 4 also has a shaft 4b with a recess or groove 4c, preferably with chamfered or beveled edges 4d. Shaft 4b is slidably fit within a cylindrical chamber 14 defined by a lower portion 2a of housing 2. Lower portion 2a of housing 2 has two chamfered or beveled apertures 2b defined therein where balls 8 are disposed.

When plunger 4 is in its locking position (the up position in Figure 1), upper surface 4e of plunger 4 presses against the inside surface 2d at the top of housing 2, and a non-recessed portion of shaft 4b is adjacent balls 8 holding them in a radially outward position (locking position) as shown in Figure 1. In this position, an element 20 is held in a locked or storage position, thus being prevented from moving. Accordingly, element 20 may be held in place against external forces such as inertial and surface or contact forces (downward in Figure 1) acting on it. Such external forces may include, for example, those exerted by gravity, an airstream, water or other biasing device such as a spring, one or more magnets, or the like. Typically, in airborne devices and projectiles, the external forces that are present may be quite high. To counter such external forces for airborne devices and projectiles in certain embodiments, the biasing force of spring 10 on plunger 4 may be about 150 pounds to about 200 pounds, e.g., 185 pounds or even higher than 200 pounds.

In a preferred embodiment, element 20 has a recess or aperture formed therein to provide space to locate the lower portion 2a of housing 2, the shaft 4b of plunger 4, and the locking balls 8. Together biasing member 10, solenoid 6, locking balls 8 and plunger 4 provide a way to reduce the force necessary to initiate deployment (e.g., of fins, panels or other devices) down to the order of a few pounds or even ounces of force.

Accordingly, in a preferred embodiment, the spring 10 has a spring force of about a pound or just ounces, and thus the solenoid need only overcome a force of about a pound or just ounces.

When circuit 12 is turned on, current flows to coil 6 inducing a magnetic field (as is well known in the art of solenoids), to move the plunger 4 downward in Figure 1. The magnetic force is preferably sufficiently strong to overcome the force of biasing member (e.g., a spring) 10. Shaft 4b moves such that recess 4c moves adjacent to balls 8, which roll or fall into the recess. The portions of balls 8 protruding beyond housing 2 no longer protrude or protrude relatively little, so as to release the member 20 from the locking device allowing it to move downward by gravity, and/or biasing device 24. Device 24 acts on member 20 pulling (or pushing) it in the downward direction in Figure 1. Alternatively, biasing device 24 acts on a member 22 pulling (or pushing) it in the upward direction in Figure 1.

Device 24 may be located above or below the member 20 or 22, as desired. The biasing device's actual location, depends on the type of device, e.g., tension spring, compression spring, other spring, resilient member, or otherwise, and depends on the position of the member 20 (or 22) that is locked, and will be evident to one of ordinary skill in the art. While two locking balls are shown, any number from one or more may be used.

Figure 2 shows the position of the locking device in the released position and with the biasing device omitted for simplification. Release occurs by sending electrical current through the coils to induce a magnetic field acting on the plunger in a direction (e.g., downward in Figures 1 and 2) opposite to the direction that the spring biases the

plunger (e.g., upward in Figures 1 and 2). The magnetic force is sufficient to overcome the spring force (e.g., greater than about a pound or just ounces) to move the plunger down sufficiently so that the recess aligns with the apertures. The balls will then enter the recess and no longer retain the member 20 (or 22) that was locked. The greater the solenoid's force, the faster the spring force will be overcome. Accordingly, the solenoid must be designed taking into account the spring force, and the desired speed of release of the locked member.

Button 4f (Figure 1) may provide for manually pressing plunger 4 down to manually release the balls 8 and test the locking device. Button 4f preferably projects above outer surface 26 of housing 2 when the plunger is in the locked position.

Figure 3 shows a portion of plunger 4 having the recess 4c, but each locking ball is replaced with a lever 30. Lever 30 is rotatable on a pivot pin 30a, and may be rotationally biased by a torsion spring (not shown), e.g., in a clockwise direction in this embodiment. The lever has a locking arm 30b for holding a locked member 120 in place. Locked member 120 may be positioned the same as member 20 or member 22 of Figures 1 and 2, as desired. The lever 30 also has a release arm 30c for rotating into recess 4c when solenoid coil 6 (Figures 1 and 2) is activated by power on circuit 12 to move plunger 4 down sufficiently so that recess 4c aligns with arm 30c, allowing arm 30c to rotate (clockwise in Figure 4) into the recess.

Because the lever rotates, the locked member 120 is locked against upward motion in this embodiment as shown in Figures 3 and 4. If the lever were oriented so that arm 30c points down in Figure 3, and the lever were of a type that rotates counterclockwise, the locked member 22 (Figures 1 and 2) may be locked against

downward movement. The location of pivot pin 30a would be moved upward, and the plunger and solenoid would ideally be positioned so that the recess 4c is below apertures $2b_1$ in the locked position, and so that the plunger is biased downward by a spring. The solenoid when activated moves the plunger upward so that the recesses 4c will align with apertures $2b_1$ in lower housing $2a_1$. In this way when the plunger is reset, its upper beveled edge will push on arm 30c rotating the lever clockwise to position it in the locking position.

In Figures 3 and 4 as shown, the plunger must move down to align the recess and apertures. When the device is set or reset to the locked position, the plunger must be moved upward so that lower beveled surface 4d rotates arm 30c counterclockwise against the torsion spring bias to put the lever back into the locking position.

In another embodiment, a staggered release may be achieved, as shown in Figures 5 to 7. In Figure 5, a housing 102 holds a plunger 104 biased upward by a spring 110. Two solenoid coils 106, 107 may be successively activated by power on source 112. When the first solenoid coil 106 is activated, plunger 104 moves partway down such that a first recess 104c in the plunger aligns with a first set of balls 108, partially releasing locked member 120. Biasing member 124 pushes (or pulls) locked member 120 downward until it is stopped by a second set of balls 108a, as shown in Figure 6.

When second solenoid coil 107 is activated, plunger 104 moves down to the position shown in Figure 7, where the second recess 105c is aligned with a second set of apertures 103b, such that second set of balls 108a move radially inward and this fully releases locked member 120.

Figures 8 and 9 show a variation of the previous embodiment, where two sets of

balls 208, 208a are released substantially simultaneously due to the plunger having one elongated recess 204c. Recess 204c is sufficiently long so that both sets of balls can enter recess 204c. There still may be a slight staggering effect to the release of the first and second sets of balls and therefore a slight staggering to the release of locked member 220 under the influence of biasing member 224, although depending on the speed with which the solenoid pushes the plunger down, this slight staggering may or may not be significant, as desired by the designer.

Figures 10 and 11 show a bomb or missile or torpedo (or an airborne device) with fins retracted before the solenoid is activated and thus locked in that position (Figure 10) and fins deployed after the solenoid is actuated and thus unlocked (Figure 11). Such device has a housing 400 and incorporates a solenoid release device 402 such as disclosed in the other embodiments herein. There is a mechanical linkage 404 to the locked member, e.g., member 22 in Figure 1. A star-shaped member 408 has grooved ends 408a which in turn prevent member 409 from moving, e.g., about a pivot point due to e.g., a torsion spring 410. When the solenoid is actuated, star member 408 is pulled upward through linkage 404 or otherwise moved out of engagement with member 409 at its end 409a, and spring 410 rotates end 409b out of engagement with fin 414, which is then deployed due to a bias outward and around a pivot point 416 connected to the fin at flange 418. In this manner, all four fins are deployed at the same time.

Figures 12 and 13 show an enlarged partial cutaway partial sectional view of another embodiment of the locking device in the locked position and released position, respectively. In this embodiment, as in others, like elements are given like reference numerals. This embodiment is similar to that of Figures 1 and 2, except that locked

member 320 is locked against upward motion under the bias of spring 324, and stopper element 321 is shown to limit the downward motion of member 320 when being reset to the locked position.

Also in Figures 12 and 13, one locking ball 8 is shown in phantom to indicate that one or two balls 8 may be used, two being preferred for balance.

By way of example, a recess formed in locked member 320 may be about or less than one half inch, e.g., about three tenths of an inch, in diameter and the diameter of the bottom of the housing may be about one quarter of an inch. The force of spring 10, and thus the solenoid specifications, may be readily determined knowing the biasing force of biasing device 324, and setting the specifications (e.g., materials and dimensions) of the locking balls, plunger, and recesses to hold the locked member 320 against the force of biasing device 324. In a preferred embodiment, as noted above, the force of spring 10 may be, e.g., on the order of ounces and thus the solenoid need only counteract this very small force in relation to the large force of the biasing member 324.

Fin deployment may be tested by actuating the solenoid. The fins may be reset, usually done manually with the aid of a tool or tools to overcome the biasing forces on the fins and other portions of the linkage. For example, once the member 20 in Figs. 1 and 2 is moved back to the position of Fig. 1, the force of biasing member 10 causes the plunger to move up and the balls 8 to move outward to the locking position, completing resetting of the device. The device is then ready for repeated use.

Although the invention has been described using specific terms, devices, and/or methods, such description is for illustrative purposes of the preferred embodiment(s) only. Changes may be made to the preferred embodiment(s) by those of ordinary skill in

the art without departing from the scope of the present invention, which is set forth in the following claims. In addition, it should be understood that aspects of the preferred embodiment(s) generally may be interchanged in whole or in part.